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SPECIFICATION OF INVENTION
TO INVENTOR'S CERTIFICATE

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(56) Temarinac M., Markovic A., and Zivkovic-Drunja, MF-AM Stereo Broadcasting: The Choice of Modulation. - IEEE Trans. on broad. - Mar. 1989 - Vol. 35, p. 79-87

(54) METHOD OF STEREO BROADCASTING, AND SYSTEM FOR PERFORMING SAME

(57) The invention relates to radio communication and can be utilized for building up stereo radio broadcasting systems operated in the amplitude modulation mode, and also for having radio stereo broadcasting in networks of multiple program wire broadcasting. The object of the invention is to provide for compatibility with mono receivers, and for simplifying stereo receivers. The novelty in the method resides in the transmitted signal being modulated according to a law defined in the Claims. The device comprises a radio transmitter and a radio receiver. The radio receiver includes: one high and intermediate frequency (HF-IF) section; two bandpass filters, one sum/difference converter, and two lower frequency filters. The radio transmitter includes one sum/difference converter, two amplifiers, two Gilbert circuits, four squarers, two lower frequency filters, three adders, two dividers, two arc tangent converters, two square root extractors, two phase modulators, two amplitude modulators, two oscillators.

2 independent Claims; 5 drawings.

The invention relates to radio communication and can be utilized in building stereo radio broadcasting systems operated in the amplitude modulation mode, and also for having radio stereo broadcasting in networks of multiple program wire broadcasting.

There is known a method of stereo radio broadcasting with division of the audio signal spectrum into two frequency bands, and their transmission in different modulation modes, and a system for implementing this method.

A drawback of this known method is its broad (theoretically, infinite) spectrum of frequencies occupied in the air by its signal. This drawback results in substantial nonlinear distortions when the stereo signal is received by a mono receiver. A drawback of the known system is extensive complexity of its stereo radio receiver.

There is further known a method of stereo radio broadcasting deemed the closest prior art of the claimed method, wherein the carrier signal is modulated by phase according to the *arctg (L-R)* law, and then by amplitude, according to the *1 + L + R* law, where *L and R* are, respectively, the audio signals of the left and right stereo channels.

The known stereo radio broadcasting system deemed the closest prior art of the claimed system comprises a radio transmitter including a sum/difference converter (SDC), the first multiplier having its first input connected to the difference output of the SDC and its second input connected to the output of the carrier signal source; an adder having its first input connected to the output of the first multiplier, and its second input connected to the carrier signal source via a 90° phase shifter; a limiter having its first input connected to the output of the adder and its output connected to the first input of the second multiplier whose second input is connected to the sum output of the SDC, and whose output is connected to the output of the device; and a stereo radio receiver comprising high and intermediate frequency sections, and a SDC, with the first input of the SDC being connected to the output of the intermediate frequency section via an amplitude detector, and with the second input of the SDC being connected to the output of the intermediate frequency section via a circuit for difference signal extraction.

A shortcoming of these known method and device of the prior art resides in the following. Domestic radio receivers, as per GOST 5651-82 "Household Radio Receiver Devices. General Specifications," have the frequency band of the intermediate frequency filters at 7 - 9 kHz, whereas even with the frequency of the transmitted audio signal equaling 4 kHz, the width of the radio signal spectrum exceeds 32 kHz. In this, the signal spectrum at the output of the intermediate frequency filter on mono radio receivers would become truncated, so that the radio signal envelope would suffer nonlinear distortion. Hence, the prime requirement put before a stereo radio broadcasting system would not be met, i.e. the requirement of its compatibility with mono radio receivers. Furthermore, this system implemented in a household stereo radio receiver is fairly complicated, and, hence, costly.

It is an object of this invention to assure compatibility with mono radio receivers, and to simplify stereo radio receivers.

This object is attained in a method of stereo radio broadcasting, wherein transmission includes adding and subtracting the left and right stereo channel signals $S_l(t)$ and $S_r(t)$, and reception includes extraction of the sum signal by its amplitude detection, and its subsequent addition and subtraction with the difference signal, with the radio signal transmitted being modulated according to the law:[1]

$$u(t) = \sqrt{V_s^2 + _n(t) + G^2(V_s + _n(t))}\cos \omega t + \operatorname{arctg}\frac{G(V_s + _n(t))}{V_s + _n(t)} + \sqrt{V_s^2 - _n(t) + G^2(V_s - _n(t)}\cos((\omega + \Omega)t + \operatorname{arctg}\frac{G(V_s - _n(t))}{V_s - _n(t)}) \quad (1)$$

[1] Given the poor legibility of these and other essentially important expressions in the *.pdf* file furnished for translation, they are reproduced in the translation as are to avoid errors in re-typing. The sole comment required is that in the sub-indexes Cyrillic "п" means "R" (right), and "л" means "L" (left) throughout the document *[Translator's Note]*.

where Ω is the width of the stereo signal spectrum;

G is Gilbert conversion; and

$V_{n+n\,(L+R)}$ and $V_{n-n\,(L-R)}$ are signals determined from the transcendent relationships (2) and (3):

$$\frac{1}{2\pi}\int_{-\Omega_{max}}^{\Omega_{max}} e^{i\omega t}\left[\int_{-\infty}^{\infty} e^{-i\omega x}\sqrt{V_n^2+n(x)+G^2(V_n+n(x))}\,dx\right]d\omega = 1+S_L(t)+S_R(t). \quad (2)$$

$$\frac{1}{2\pi}\int_{-\Omega_{max}}^{\Omega_{max}} e^{i\omega t}\left[\int_{-\infty}^{\infty} e^{-i\omega x}\sqrt{V_n^2-n(x)+G^2(V_n-n(x))}\,dx\right]d\omega = 1+S_L(t)-S_R(t) \quad (3)$$

and also satisfying the spectrum limitation conditions (4) and (5):

$$\frac{1}{2\pi}\int_{-\Omega_{max}}^{\Omega_{max}} e^{i\omega t}\left[\int_{-\infty}^{\infty} e^{-i\omega x} V_{n+n}(x)\,dx\right] d\omega = V_{n+n}(t). \quad (4)$$

$$\frac{1}{2\pi}\int_{-\Omega_{max}}^{\Omega_{max}} e^{i\omega t}\left[\int_{-\infty}^{\infty} e^{-i\omega x} V_{n-n}(x)\,dx\right] d\omega = V_{n-n}(t). \quad (5)$$

where Ω_{max} is maximum frequency of the spectrum of the transmitted audio signals of the left and right stereo channels S_L and S_R; and reception further includes additional frequency filtration, and a difference signal is extracted by way of amplitude detection.

The object is further attained in a stereo system comprising a radio receiver device including a high frequency and intermediate frequency (HF-IF) section, the first amplitude detector having its input connected via a bandpass filter to the output of the HF-IF section, and also a sum/difference converter (SDC) having its first input connected to the output of the amplitude detector; and a radio transmitter device comprising a sum/difference converter whose inputs are the inputs of the radio transmitter device; with the radio receiver device including additionally a bandpass filter having its input connected to the output of the HF-IF section, and the second amplitude detector having its input connected to the output of the additional bandpass filter whose output is connected to the second input of the SDC; and also the first and second lower frequency filters having their inputs connected to the sum and difference outputs of the SDC, and the outputs connected to the outputs of the radio receiver device; and with the radio transmitter device including an additional adder whose output serves as the output of the radio transmitter device, and whose first and second inputs are connected to the outputs of the SDC via circuits including each an amplifier whose non-inverting input is connected to the output of the SDC, a Gilbert circuit having its input connected to the output of the amplifier, a divider whose first and second inputs are connected to the input and output of the Gilbert circuit, the

first and second squarers whose inputs are connected, respectively, to the input and output of the Gilbert circuit, an adder whose first and second inputs are connected to the outputs of the first and second squarers, a square root extractor having its input connected to the output of the adder, a lower frequency filter connected between the output of the square root extractor and the inverting input of the amplifier, an arc tangent converter having its input connected to the output of the divider, a sine voltage generator, a phase modulator whose first input is connected to the output of the arc tangent converter and whose second input is connected to the output of the sine voltage generator, an amplitude modulator whose first input is connected to the output of the square root extractor and whose second input is connected to the output of the phase modulator, and whose output is connected to the input of the additional adder.

Fig. 1 of the appended drawings shows the spectrum of a radio signal of type (1); Fig. 2 shows a block-unit diagram of the radio receiver device; Fig. 3 shows a block-unit diagram of the radio transmitter device; Fig. 4 illustrates spectra of a stereo radio signal when a harmonic audio signal is fed to the input of the left channel of the radio transmitter; and Fig. 5 illustrates spectra of signals at the output of the left channel of stereo radio receiver.

The spectrum of a radio signal of type (1) shown in Fig. 1 is made up of two frequency-spaced parts of which one corresponds to the first addend of expression (1), and the other one corresponds to the second addend of expression (1). The value of the spectrum width of the radio signal is selected to satisfy the condition:

$$\Omega = 2\,\Omega_{max} \qquad (6)$$

where Ω_{max} is maximum frequency of the spectrum of the transmitted audio signal. Proceeding from the requirement of compatibility with mono radio receivers which, as it has been stated, have a bandpass width equaling 7 ... 9 kHz, the value of Ω may be selected to equal 14 kHz. In this, the mono radio receiver would be tuned to the lower-frequency half of the spectrum corresponding to the first addend of expression (1). The envelope of this first addend is compatible with mono radio receivers: this transpires from expression (2). Hence, undistorted reception of a stereo signal by a mono radio receiver is made possible.

Numerals in Figs. 2 - 3 refer to:

1 - high and intermediate frequency section;
2, 3 - bandpass filters;
4, 5 - amplitude detectors;
6, 9 - sum/difference converters;
7, 8, 20, 25 - lower-frequency filters;
10, 11 - amplifiers;
12, 13 - Gilbert circuits;
14, 15, 18, 19 - squarers;
16, 17 - dividers;
21, 23, 24 - dividers;
22, 23 - arc tangent converters;
26, 29 - square root extractors;
27, 28 - phase modulators;
30, 33 - amplitude modulators; and
31, 32 - generators.

The stereo radio receiver device illustrated schematically in Fig. 2 operates as follows.

A signal of type (1) is sent from the output of the HF-IF section 1 to the bandpass filters 2 and 3. The bandpass widths of these filters equal $\Omega/2$, and the central frequencies of the tuning of these filters are shifted through $\Omega/2$ relative to one another; thus, the following signal will be extracted at the output of one of the two filters:

$$u_{a+n}(t) = \sqrt{V_a^2 + n(t) + G^2(V_a + n(t))}\cos(\omega t -$$
$$- \operatorname{arctg}\frac{G(V_a + n(t))}{V_a + n(t)}), \qquad (7)$$

and the following signal will be extracted at the output of the other one of the two filters:

$$u_{a-n}(t) = \sqrt{V_a^2 - n(t) + G^2(V_a - n(t))}\cos((\omega + \Omega)t +$$
$$+ \operatorname{arctg}\frac{G(V_a - n(t))}{V_a - n(t)}) \qquad (8).$$

Proceeding from expressions (2) and (3), the spectra of envelope signals (7) and (8) in the audio frequency range would coincide with the spectra of signals $S_L(t) + S_R(t)$ and $S_L(t) - S_R(t)$. Therefore, after amplitude detection and sum/difference conversion, the outputs of the stereo radio receiver would be:

$$U_L = (S_L(t) + S_R(t)) + (S_L(t) - S_R(t)) = 2\,S_L(t) \qquad (9)$$
$$U_R = (S_L(t) + S_R(t)) - (S_L(t) - S_R(t)) = 2\,S_R(t) \qquad (10).$$

The stereo radio transmitter device illustrated in Fig. 3 operates as follows. Audio signals of the left and right stereo channels are sent to the inputs of the SDC 9, with a signal $1 + S_l(t) + S_r(t)$ produced at one output of the SDC 9, and a signal $1 + S_L(t) - S_R(t)$ produced at its other output. Let us now consider the operation of the top (in the diagram) channel. With adequately great amplification supported by the amplifier 10, signals at its inverting and non-inverting inputs may be held equal. Let us denote as P(t) the output signal of the amplifier 10. Then, the signal at the output of the Gilbert circuit 12 will be G(P(t)). The signal at the output of the square root extractor 26 will be:

$$\sqrt{P^2(t) + G^2(P)(t))},$$

and the signal at the output of the lower frequency filter will be:

$$\frac{1}{2\pi}\int_{-\Omega_{max}}^{\Omega_{max}} e^{i\omega t}\left[\int_{-\infty}^{\infty} e^{-i\omega x}\sqrt{P^2(x) + G^2(P(x))}\,dx\right]d\omega =$$
$$= 1 + S_L(t) + S_R(t). \qquad (11)$$

It transpires from the above expression that function P(t) meets the requirement put by equation (2) upon function $V_{L+R}(t)$, i.e.

$$P(t) = V_{L+R}(t)\,. \qquad (12)$$

Hence, the signal at the output of the divider 16 will be:

$$u_Д = \frac{-G(V_л + n(t))}{V_л + n(t)} \qquad (13)$$

The condition (4) is met owing to the signals coming to the inputs of the amplifier 10 being limited in their spectrum by frequency Ω_{max} [The lower-frequency filter 20 has the cutoff frequency of Ω_{max}, and the audio signal $S_L(t) + S_R(t)$ is limited by this frequency by definition].

Given (13), the high-frequency input signal of the amplitude modulator 30 will be:

$$u_\Phi = \cos\left(\omega t - \mathrm{arctg}\frac{G(V_л + n(t))}{V_л + n(t)}\right), \qquad (14)$$

and the radio signal produced at its output will be of type (7).

The difference between the top and bottom channels is in that the tuning frequency of the bottom channel generator 32 is selected to equal $\omega + \Omega$, and the Gilbert circuit of the top channel performs not direct, but inverse Gilbert conversion. Given this fact, the signal of type (8) will be produced at the output of the amplitude modulator of the bottom channel. In this, the signal of type (1) will be sent out by the output of the additional adder 34.

Fig. 4 of the appended drawings illustrates the spectra of signals in the system of the prior art [*a*] and in the system of the invention [*b*] when the signal sent to the input of the left channel of the stereo radio transmitters is $S_L = 0.5 \cos 2\pi f_L t$, where f_L = 4 kHz. This proceeds from an assumption that in the system of the invention Ω = 24 kHz.

The signal spectrum in the system of the invention is theoretically confined. In the case being considered its symmetry is explained by the absence of the right stereo signal at the input of the radio transmitter [i.e. $S_L + S_R = S_L - S_R$, and $V_{L+R} = V_{L-R}$].

Computer modeling has shown that the harmonics of the stereo radio signal spectrum are in the following ratio [only for the model of the transmitter input signals as being now discussed]: 0.933; 0.5; 0.066.

With this model of radio signal being received by the stereo radio receiver illustrated in Fig. 2, the following takes place. One of the bandpass filters would separate the three lower (by frequency) harmonics, and the other bandpass filter would separate the three upper ones. The signal envelopes at the output of the bandpass filters would be the same, described by $1 + 0.5 \cos 2\pi f_L t$. Hence, the voltage at the difference output of the SDC 6 of the radio receiver, corresponding to the right channel, would be zero, and the other output of the receiver corresponding to the left channel would have double voltage of the signal of the left channel being transmitted.

Fig. 5 of the appended drawings shows spectra of the signals at the output of the left channel of the stereo radio receiver of the prior art [*a*] and of the radio receiver of the system of the invention [*b*] when signals whose spectra are shown in Fig. 4 are transmitted. In the radio receiver of the prior art, the output signal spectrum contains, beside the desired component, an infinite number of parasite harmonics. This is due to the fact that the radio signal spectrum in the method of the prior art is infinite, while the bandpass filter transmission band is finite. This interferes with the law of signal modulation at the output of the bandpass filter of the radio receiver, and, consequently, leads to the onset of nonlinear distortions.

In the method of the invention the radio signal spectrum is theoretically confined, and passes in its entirety through the filters of the radio receiver. Thus, there are theoretically no signal distortions at the output of the stereo radio receiver.

A further advantage of the method and system of stereo broadcasting according to the invention over the prior art is the theoretically complete absence of transition distortions across the stereo channels. This is due to the fact that in the method of the prior art truncation of the radio signal spectrum in the receiver results in phase modulation of the radio signal causing its parasite amplitude modulation at the bandpass filter output. In the method of the invention this effect is non-existent, as no truncation of the radio signal spectrum is performed.

What is claimed is:

1. A method of stereo radio broadcasting, wherein transmission includes adding and subtracting the left and right stereo channel signals $S_L(t)$ and $S_R(t)$, and reception includes extraction of the sum signal by its amplitude detection, and its subsequent addition and subtraction with the difference signal, **characterized in that,** in order to assure compatibility with mono radio receivers and to simplify stereo radio receivers, the radio signal being transmitted is modulated according to the law:[2]

$$u(t) = \sqrt{V_{L+R}^2(t) + G^2(V_{L+R}(t))}\cos\left(\omega t + \operatorname{arctg}\frac{G(V_{L+R}(t))}{V_{L+R}(t)}\right) + \sqrt{V_{L-R}^2(t) + G^2(V_{L-R}(t))}\cos\left((\omega + \Omega)t + \operatorname{arctg}\frac{G(V_{L-R}(t))}{V_{L-R}(t)}\right) \qquad (1)$$

where Ω is the width of the stereo signal spectrum;

G is Gilbert conversion; and

V_{L+R} and V_{L-R} are signals determined from the transcendent relationships (2) and (3):

$$\frac{1}{2\pi}\int_{-\Omega_{max}}^{\Omega_{max}} e^{i\omega t}\left[\int_{-\infty}^{\infty} e^{-i\omega x}\sqrt{V_{L+R}^2(x) + G^2(V_{L+R}(x))}\,dx\right]d\omega = 1 + S_L(t) + S_R(t). \qquad (2)$$

$$\frac{1}{2\pi}\int_{-\Omega_{max}}^{\Omega_{max}} e^{i\omega t}\left[\int_{-\infty}^{\infty} e^{-i\omega x}\sqrt{V_{L-R}^2(x) + G^2(V_{L-R}(x))}\,dx\right]d\omega = 1 + S_L(t) - S_R(t) \qquad (3)$$

and also satisfying the spectrum limitation conditions (4) and (5):

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[2] See Note 1.

$$\frac{1}{2\pi}\int_{-\Omega_{max}}^{\Omega_{max}} e^{i\omega t}\left[\int_{-\infty}^{\infty} e^{-i\omega x} V_{\text{л+п}}(x)dx\right] d\omega = $$
$$= V_{\text{л+п}}(t), \qquad (4)$$

$$\frac{1}{2\pi}\int_{-\Omega_{max}}^{\Omega_{max}} e^{i\omega t}\left[\int_{-\infty}^{\infty} e^{-i\omega x} V_{\text{л-п}}(x)dx\right] d\omega = $$
$$= V_{\text{л-п}}(t). \qquad (5)$$

where Ω_{max} is maximum frequency of the spectrum of the transmitted audio signals of the left and right stereo channels $S_L(t)$ and $S_R(t)$; and reception further includes additional frequency filtration, and a difference signal is extracted by way of amplitude detection.

2. A system for stereo radio broadcasting, comprising a radio receiver device including a high frequency and intermediate frequency (HF-IF) section, the first amplitude detector having its input connected via a bandpass filter to the output of the HF-IF section, and also a sum/difference converter (SDC) having its first input connected to the output of the amplitude detector; and a radio transmitter device comprising a sum/difference converter whose inputs are the inputs of the radio transmitter device; with the radio receiver device including additionally a bandpass filter having its input connected to the output of the HF-IF section, and the second amplitude detector having its input connected to the output of the additional bandpass filter whose output is connected to the second input of the SDC; and also the first and second lower frequency filters having their inputs connected to the sum and difference outputs of the SDC, and the outputs connected to the outputs of the radio receiver device; and with the radio transmitter device including an additional adder whose output serves as the output of the radio transmitter device, and whose first and second inputs are connected to the outputs of the SDC via circuits including each an amplifier whose non-inverting input is connected to the output of the SDC, a Gilbert circuit having its input connected to the output of the amplifier, a divider whose first and second inputs are connected to the input and output of the Gilbert circuit, the first and second squarers whose inputs are connected, respectively, to the input and output of the Gilbert circuit, an adder whose first and second inputs are connected to the outputs of the first and second squarers, a square root extractor having its input connected to the output of the adder, a lower frequency filter connected between the output of the square root extractor and the inverting input of the amplifier, an arc tangent converter having its input connected to the output of the divider, a sine voltage generator, a phase modulator whose first input is connected to the output of the arc tangent converter and whose second input is connected to the output of the sine voltage generator, an amplitude modulator whose first input is connected to the output of the square root extractor and whose second input is connected to the output of the phase modulator, and whose output is connected to the input of the additional adder.

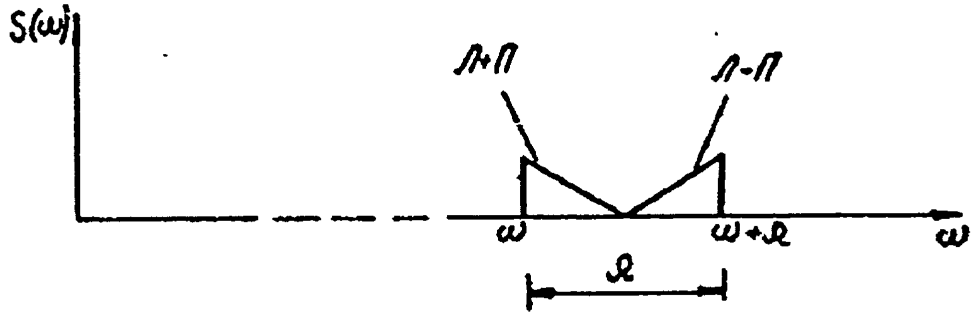

Fig. 1

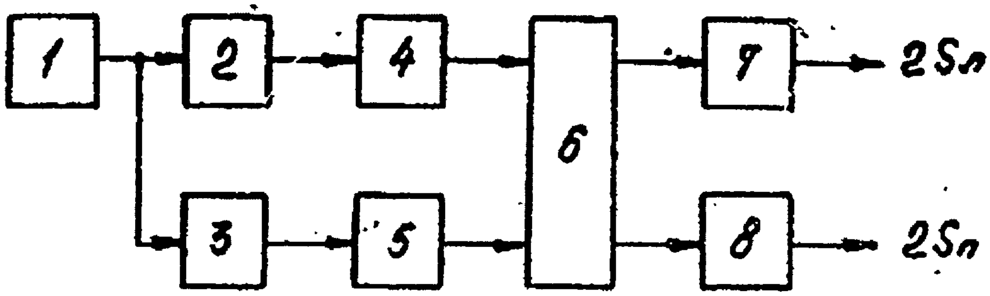

Fig. 2

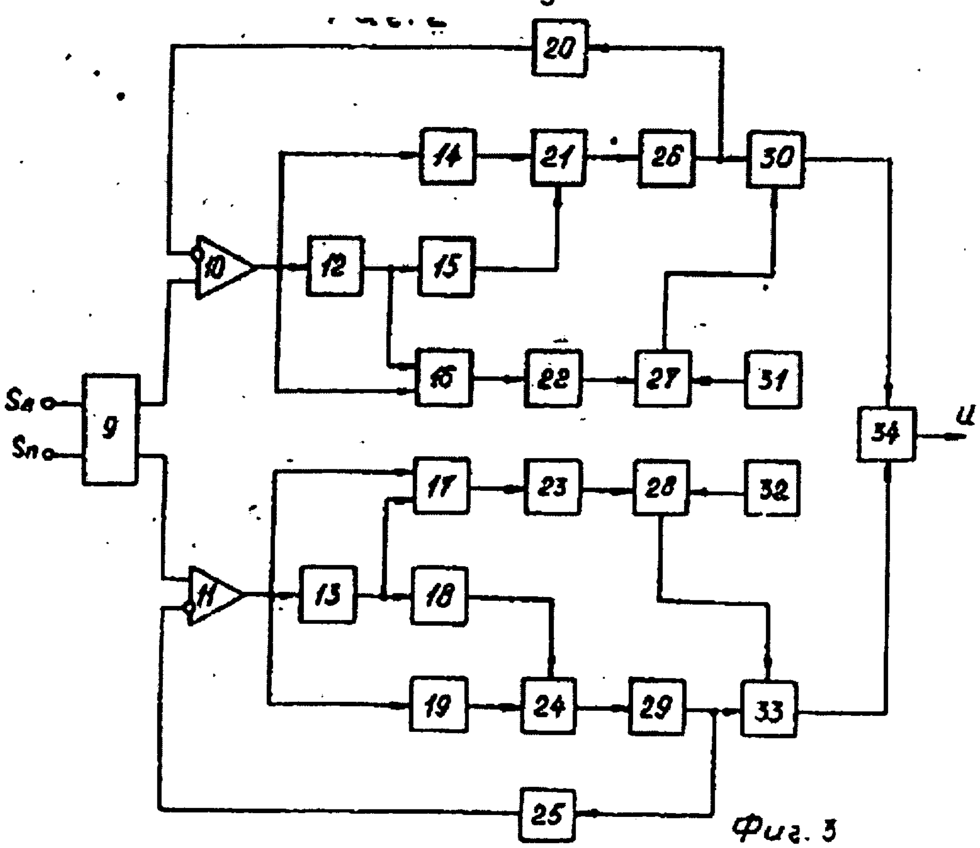

Fig. 3

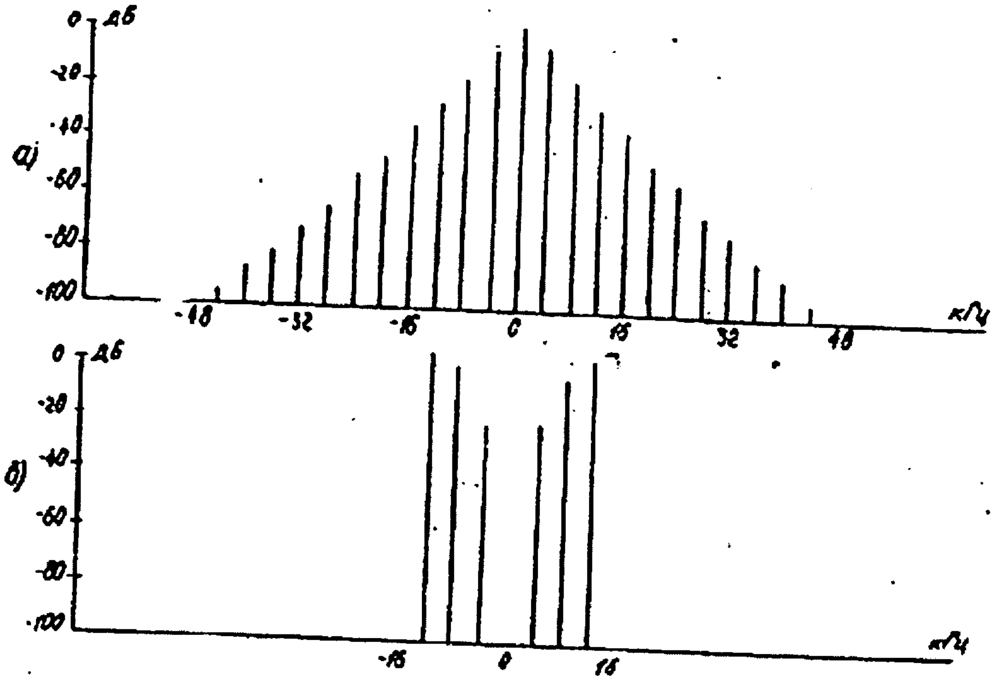
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Fig. 4

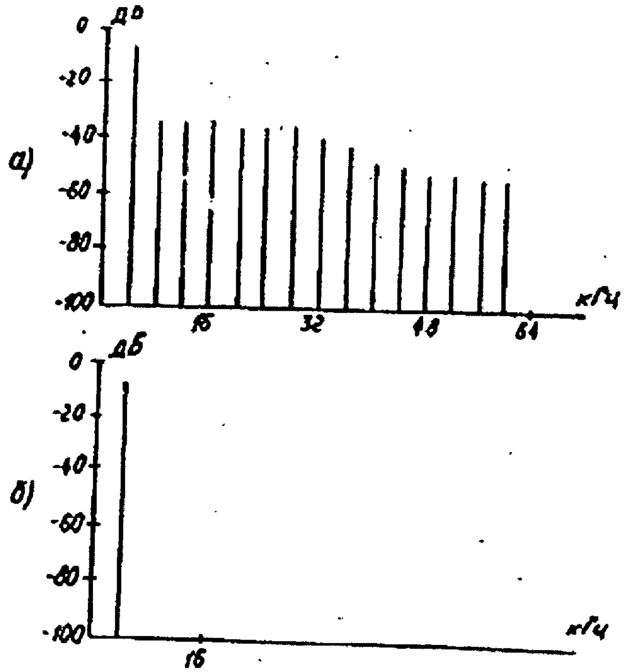
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Fig. 5